Increasing Meat Production in Goats through Crossbreeding

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Abstract
In Romania, research on enhancing meat production in goats through hybridization is sparse, with studies being conducted primarily at R.D.I.S.G.B. Palas Constanta. This study aims to highlight the benefits of crossbreeding the Carpatina and Boer breeds in terms of all morphoproductive indices. The objective is to develop a Romanian goat breed tailored for meat production, which is well-suited to Romanian conditions. In this regard, the research focuses on analyzing the main morphoproductive indicators of the newly created R_1 (75% Boer x 25% Carpatina) and F_1 (50% Boer x 50% Carpatina) populations compared to the Carpatina breed (control group). The body weight was 12.87% higher in R_1 hybrids (75% Boer x 25% Carpatina) compared to the F_1 group (50% Boer x 50% Carpatina) and 17.67% higher compared to Carpatina breed kids. The average daily weight gain in kids during the fattening period was 130.80 g (Carpatina breed) and 185.30 g (R_1 hybrids). The difference between the R_1 and F_1 study groups was 17.85% concerning the average daily gain, and the F_1 hybrid group achieved an average daily gain that was 20.21% higher compared to the Carpatina breed kids. The specific energy and protein consumption in the R_1 and F_1 hybrid groups were lower than in the Carpatina breed kids. The experimental slaughters revealed superior qualities in hybrid kids compared to those of the Carpatina breed.

Keywords: buckling, carpatina, goats, hybrids, meat.

1. Introduction

The orientation and development of goat breeding in the direction of meat production is determined by the demand on the food market for lean meat, while there are also tendencies to implement a dietary diet, limited in fat and especially in saturated lipids. In recent years, there has been an increase interest in goat meat, which provides proteins with high biological value and healthy fats due to a high ratio between saturated and unsaturated fatty acids as well as a low cholesterol content. In Romania, there is a small number of papers aimed at increasing the quality of goat meat production through hybridization. The current paper aims to highlight the advantages of crossbreeding goats from the Carpatina breed with goats from the Boer breed on meat production, looking at the qualitative and quantitative aspects of this production. On an international level, the research carried out by Lu, Prieto, and Van Niekerk [1-3], presented the advantages of using the Boer breed to increase meat production. Results obtained by the research team from R.D.I.S.G.B. Palas [4] show a good increase in the performances of Boer x Carpatina crossbred kids as well as the obtaining

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of higher quality carcasses compared to the Carpatina carcass.
The results obtained from the research carried out support the idea of continuing the research works, with the aim of obtaining a Romanian breed of goats specialized for meat production, adapted to the environmental conditions in Romania.

2. Materials and methods

The research was carried out by organizing 3 batches as follows – batch 1: 10 kids from the R_1 population (75% Boer x 25% Carpathian), batch 2: 15 kids from the F_1 population (50% Boer x 50% Carpathian) and batch 3: 20 kids from the Carpathian breed. Measurements and weighing were carried out on these populations, calculating the growth speed of the kids at fattening, the specific feed consumption, and nutrients as well as the data obtained after slaughtering.
The administered feeds were weighed daily, and the feed residues were collected every 2-3 days. Fattening was carried out from the age of the kids of 102 - 104 days over a period of 70 days, until the average body weight of the kids was about 30 kg/head. A feed mixture with the following nutritional value was used for fattening: N.U.=0.78; D.P.=128.1; intestinal digestible protein=96.3 g; intestinal digestible protein allowed by the energy content=75.6g, after the completion of fattening, 3 kids from each genotype were retained and subjected to a diet for 24 hours, after which they were sacrificed. The yield at slaughter and the quality indices of the carcasses were determined, after cooling them for 24 hours at a temperature of +2 +4 degrees Celsius.

Two slaughter yields were determined:

$$\text{Yield 1} = \frac{\text{Cooled weight carcass (kg)}}{\text{Living weight (kg/head)}} \text{ x 100}$$

$$\text{Yield 2} = \frac{\text{Cooled weight carcass (kg)}}{\text{Empty live weight } \left(\frac{\text{kg}}{\text{head}}\right) *} \text{x 100}$$

* Empty live weight - live weight from which the contents of the digestive tube have been subtracted [5].
Each carcass was sectioned lengthwise along the spinal line into two equal halves, each right half of the carcass was dissected separating the muscles from the bones, the covering and intermuscular fat, the thigh was sectioned perpendicular to the longitudinal axis of the femur at its half, copying the outline of the thigh section and section of the femur. The half-carcass was sectioned between the D12 and D13 vertebrae perpendicular to the axis of the vertebral column and the outline of the m. Longissimus dorsi was copied on the tracing paper. The carcasses and their components (muscles, bones, fat) were weighed on an electronic scale with a precision of±5g.
The thigh muscularity index was calculated using Purchas formula:

$\text{T. M. I.} = \frac{\sqrt{\text{G/F}}}{\text{LF}}$, where:

G - the weight of the muscles (in grams) grouped around the femur (m. quadriceps femoris, m. sartorius, m. semitendinosus and m. biceps femoris).
F – femur weight (in grams)
LF – femur length (in centimeters)
All data were processed and interpreted statistically by the Fisher test [6].

3. Results and discussion

At the end of the fattening period the average body weight of the 3 batches was 28.24-33.23 kg. The batch of R_1 kids (75% Boer x 25% Carpatina) achieved a total average body weight higher by 12.87% (significant differences, $p<0.05$) compared to the F_1 hybrids (50% Boer x 50% Carpatina) and by 17.67% (significant differences, $p<0.05$) compared to the Carpatina goats. Also, the F_1 hybrids had a body weight at the end of fattening higher than the batch of kids from the Carpatina breed kids by 4.25%. The total gain achieved by the three batches during the entire period was 9.16 - 12.98 kg, the highest value being found in the R_1 hybrids.
Regarding the average daily weight gain, it oscillated between 130.80 g (Carpatina breed) and 185.30 g (R_1 hybrids). The R_1 hybrids achieved an average daily increase higher than the F_1 hybrids by 17.85%, the differences being significant ($p<0.05$) and 41.67% higher compared to the Carpatina breed kids, the differences being very significant ($p<0.001$). The group of F_1 hybrids achieved a higher average daily increase by 20.21% compared to the group of kids from the Carpatina breed, the

differences being significant ($p<0.05$). The average body weight of the 3 batches taken in the study showed close values, it being between 18.06 kg and 19.98 kg, difference between batches being insignificant ($p>0.05$) as seen in Table 1.

Table 1. Weight gain of kids according to genotype

No. crt.	Genotype	Body weight (kg)		Weight gain	
		At the beginning of fattening	At the end of fattening	Total weight (kg)	Average daily gain (g)
		$\overline{X} \pm S_{\overline{x}}$	$\overline{X} \pm S_{\overline{x}}$	$\overline{X} \pm S_{\overline{x}}$	$\overline{X} \pm S_{\overline{x}}$
1	R_1 Boer x Carpatina	19.98±0.97	33.23±2.19	12.98±1.17	185.30±16.79
2	F_1 Boer x Carpatina	18.06±0.65	29.44 ±1.18	11.02±0.66	157.23±.46
3	Carpatina breed	18.65±0.74	28.24± 0.98	9.16±0.52	130.80±7.37

Energy consumption/kg live weight gain was 5.02-6.50 N.U., this being lower in R_1 hybrids by 12.23% compared to F_1 hybrids and by 22.77% compared to Carpatina breed kids. To achieve 1kg live weight gain, the F_1 hybrids consumed less N.U. by 12.0% compared to the group of kids from the Carpatina breed. Regarding the specific protein consumption, it was the lowest in the R_1 hybrids, being 12.17% lower than the F_1 hybrids and 22.94% lower than the performance of the Carpatina breed kids. The consumption of feed and nutrients obtained within the three batches belongin to different genotypes are presented in Table 2.

Table 2. Feed consumption by young male goats according to genotype

No.	Genotype	Duration of fattening (days)	Consumption of feed mixture		N.U. consumption			D.P. consumption		
			Total period (kg/head)	Feed per head and day (kg/head)	Total period (kg/head)	Feed per head and day (kg/head)	For an extra kg	Total period	Forage per head and day (g)	For an extra Kg (g)
1	R_1 Boer x Carpatina	70	83.3	1.19	64.97	0.93	5.02	10.67	152	823
2	F_1 Boer x Carpatina	70	80.5	1.15	62.79	0.90	5.72	8.04	147	937
3	Carpatina breed	70	76.3	1.09	59.51	0.85	6.50	7.62	140	1068

The highest R1 yield at slaughter was achieved by the R_1 Boer x Carpatina hybrids, with a value of 51.73%, followed by the F_1 hybrids where the yield at slaughter was 47.37% and finally the group of kids from the Carpatina breed where then yield R1 was 43.27%. Between the R_1 Boer x Carpatina hybrids and the Carpatina breed kids, the difference regarding the yield 1 at slaughter was 8.46 percentage points and between the F_1 Boer x Carpatina hybrids the difference was 4.1 percentage points. Also, between R_1 and F_1 hybrids the difference was 4.4 percentage points in favor of R_1 hybrids. The yield 2 at slaughter had higher values than yield 1 within the three genotypes, they were between 52.13% and 56.87%. Between the R_1 hybrids and the Carpatina breed kids, the difference was 4.7 percentage points in favor of the R_1 hybrids, and between the F_1 and Carpatina hybrids, the difference was 1.3 percentage points in favor of the F_1 hybrids. Also, the R_1 hybrids achieved a higher yield 2 at slaughter by 3.4 percentage points compared to the F_1 Boer x Carpatina hybrids. The average weight at slaughter was 30.17-33.27 kg, while the average empty live weight had values between 25.02 kg and 30.27 kg, these being dependent on the genotype, the highest values being found in R_1 Boer x Carpatina hybrids, and it is presented in Table 3.

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Table 3. Body weight and yield at slaughter in intensively fattened kids according to genotype

No.	Genotype	Live weight before slaughter (kg)	Empty live weight (kg)	Slaughter yield (%)	
		$\overline{X} \pm S_{\overline{x}}$	$\overline{X} \pm S_{\overline{x}}$	Y1	Y2
1	R_1 Boer x Carpatina	33.27±1.13	30.27±0.96	51.73	56.87
2	F_1 Boer x Carpatina	32.33±1.20	28.65±1.11	47.37	53.47
3	Carpatina breed	30.17±0.93	25.02±0.56	43.27	52.13

Within the three genotypes, it can be seen in table 4 that the three transposed pieces (the gigot, the back, and the rest of the carcass) occupied a similar weight, this being 30.14-31.13% for the gigot, 20.21 - 20.92% for the back and 48.66 - 49.29% for the rest of the case. From the presented table it follows that there are no significant differences ($p>0.05$) between the three genotypes regarding the weight of the gigot, spot, and the rest of the carcass in the three genotypes.

Table 4. Proportion of carcass cuts by genotype

No.	Genotype	Semi-carcass weight (kg)	The share of cut pieces					
			gigot		shoulder		Rest of carcass	
			Weight(kg)	%	Weight (kg)	%	Weight(kg)	%
		$\overline{X} \pm S_{\overline{x}}$	$\overline{X} \pm S_{\overline{x}}$		$\overline{X} \pm S_{\overline{x}}$		$\overline{X} \pm S_{\overline{x}}$	
1	R_1 Boer x Carpatina	6.55±0.22	1.99±0.08	30.38	1.37±0.55	20.92	3.19±0.09	48.70
2	F_1 Boer x Carpatina	7.73±0.32	2.33±0.10	30.14	1.59±0.06	20.57	3.81±0.19	49.29
3	Carpatina breed	8.61±0.30	2.68±0.13	31.13	1.74±0.04	20.21	4.19±0.15	48.66

If the meat and bone content is analyzed, it can be seen that R_1 Boer x Carpatina hybrids had 79.47% meat and 20.37% bones in the carcass, and the F_1 Boer x Carpatina hybrids had 78.12% meat and 21.77% bones in the carcass, compared to the Carpatina kids whose carcasses had 75.21% meat and 24.77% bones. The differences between the batches of hybrids and the batch of kids from the Carpatina breed regarding the content of meat and bones were significant ($p<0.05$) from a statistical point of view. It can be seen in table 5 that the tissue composition of the carcasses obtained after the control slaughter shows that the best carcasses were found in the R_1 and F_1 hybrid kids compared to the Carpathian breed.

Table 5. The tissue composition of carcasses according to genotype during intensive fattening

No.	Genotype	Weight of tissues			
		Muscle (%)	Bones (%)	Fat (%)	Meat (%)
1	R_1 Boer x Carpatina	63.59	20.37	15.88	79.47
2	F_1 Boer x Carpatina	61.93	21.77	16.19	78.12
3	Carpatina breed	60.05	24.77	15.16	75.21

*Meat represents muscles taken together with covering and intramuscular fat.

Table 6 shows that the R_1 Boer x Carpatina hybrids had the highest thigh section area value, which was 108.78 cm^2, which is 28.4% higher compared to the Carpatina breed kids where the thigh section area was 84.75 cm^2.

In the F_1 Boer x Carpatina hybrids, the area of the thigh section was 101.59 cm^2, being 19.9% larger than the Carpatina breed kids.

The differences between the hybrid kids and the Carpatina breed kids were statistically significant ($p<0.05$), while between the groups of R_1 and F_1 hybrids the differences were insignificant ($p>0.05$).

Table 6. The area of the thigh section depending on the genotype

No.	Genotype	Section area (cm^2)	Differences between genotypes (±, %) and significance (Fisher test)		
		$\overline{X} \pm S_{\overline{x}}$	1 versus 3	2 versus 3	1 versus 2
1	R_1 Boer x Carpatina	108.78±6.71	+28.4	+19.9	+17.1
2	F_1 Boer x Carpatina	101.59±4.88	p<0.05	p<0.05	p>0.05
3	Carpatina breed	84.75±2.33	Significant	Significant	Insignificant

It can be noted that in the R_1 Boer x Carpatina hybrids, the Longissimus Dorsi muscle had an area of 12.84 cm^2, which is 65.7% larger compared to the group of kids from the Carpatina breed, where the area of the section was 7.75 cm^2. In the F_1 Boer x Carpatina hybrids, the section area of the Longissimus Dorsi muscle was 10.52 cm^2, being 35.7% higher compared to the Carpatina kids. Regarding the existing differences between the hybrids, it can be noted that the R_1 Boer x Carpatina hybrids have a 22.1% larger surface area of the Longissimus Dorsi muscle compared to the F_1 Boer x Carpatina hybrids, the differences being significant ($p<0.05$). Table 7 shows the section area of the Longissimus Dorsi muscle for the three studied genotypes. Table 8 shows the surface of the femur section for the three studied genotypes.

The area of the femur section in the three genotypes was 2.84-3.20 cm^2 between them, there being no significant differences.

Table 7. The surface of the Longissimus Dorsi muscle depending on the genotype

No.crt.	Genotype	Section area (cm^2)	Differences between genotypes (±, %) and significance by Fisher test		
		$\bar{X} \pm S_{\bar{x}}$	1 versus 3	2 versus 3	1 versus 2
1	R_1 Boer x Carpatina	12.84±0.20	+65.7	+35.7	+17.1
2	F_1 Boer x Carpatina	10.52±0.58	p<0.001	p<0.05	p<0.05
3	Carpatina breed	7.75±0.58	Very significant	Significant	Significant

Table 8. The surface of the femur section depending on the genotype

No. crt.	genotype	Section area (cm^2)	Differences between genotypes (±, %) and significance by Fisher test		
		$\bar{X} \pm S_{\bar{x}}$	1 versus 3	2 versus 3	1 versus 2
1	R_1 Boer x Carpatina	2.88±0.10	+1.4	+12.7	-10.0
2	F_1 Boer x Carpatina	3.20±0.29	p>0.05	p>0.05	p>0.05
3	Carpatina breed	2.84±0.34	Insignificant	Insignificant	Insignificant

The thigh muscularity index had values between 0.37 and 0.48, the highest value being found in the R_1 hybrids where the muscularity index was 29.7% higher than the group of kids from the Carpatina breed (very significant differences, $p<0.001$) and by 9.1% compared to F_1 Boer x Carpatina hybrids, the differences being insignificant ($p>0.05$). It is shown in table 9 that thigh muscularity index had values between 0.37 and 0.48. Also, the F_1 Boer x Carpatina crossbreeds had a higher thigh muscularity index value compared to the group of Carpatina breed kids, the differences being significant ($p<0.05$).

Table 9. Thigh muscularity index (TMI) values according to genotype

No.crt.	Genotype	TMI	Differences between genotypes (±, %) and significance by Fisher test		
		$\bar{X} \pm S_{\bar{x}}$	1 versus 3	2 versus 3	1 versus 2
1	R_1 Boer x Carpatina	0.48±0.01	+29.7	+18.9	+9.1
2	F_1 Boer x Carpatina	0.44±0.02	p<0.001	p<0.05	p>0.05
3	Carpatina breed	0.37±0.01	Very significant	Significant	Insignificant

4. Conclusions

The average body weight of the 3 groups at the beginning of the experimental period was between 18.06 kg and 19.98 kg, the differences between the groups being insignificant;

At the end of fattening, the batch of R_1 hybrid kids achieved an average body weight higher by 12.87% (significant differences, $p<0.05$) than the F_1 hybrids and by 17.67% (significant differences, $p<0.05$) compared to the Carpatina breed kids;

The average daily gain achieved during fattening was between 130.80g and 185.30g, the R_1 hybrids achieving an average daily gain higher than the F_1 hybrids by 17.85%, the differences being significant ($p<0.05$) and 41.67% higher compared to the kids from Carpatina breed, the differences being very significant ($p<0.001$);

The average consumption of nutrients per head and day in the 3 batches was between 0.85-0.93 N.U. and 140-152 g D.P.;

The specific consumption of nutrients was 5.02-6.50 N.U. and 823-1068 g D.P. Energy consumption/kg live weight was lower in R_1 hybrids by 12.23% compared to F1 hybrids and 22.77% lower compared to Carpatina breed kids. The F_1 hybrids consumed less N.U./kg live weight gain by 12% compared to the batch of kids from the Carpatina breed. Regarding the specific protein consumption, it was the lowest in the R_1 hybrids (823 g), by 12.17% compared to the F_1 hybrids (937 g) and by 22.94% lower compared to the performance of the Carpatina breed kids, which for 1 kg increased live weight they consumed 1068 g D.P;

The slaughter yield 1 was between 43.27% (Carpatina breed batch) and 51.73% R_1 hybrids. Between the R_1 hybrids and the Carpatina breed kids, the difference regarding the slaughter yield was 8.46 percentage points in favor of the R_1 hybrids, the differences being significant ($p<0.05$);
Within the 3 genotypes, the weight of the 3 sliced pieces presented close values within the 3 batches: the jig 30.14-31.13%, the back 20.21-20.92% and the rest of the carcass 48.66-49.29%;
The tissue composition of the carcasses was characterized by the following values: meat 75.21-79.47%, fat 15.16-16.19% and bones 20.37-24.77%. Compared to kids from the Carpatina breed, R_1 hybrids had more meat in the carcass by 4.26 percentage points and by 4.4 percentage points less bones, the differences being significant ($p<0.05$);
The R_1 hybrids (75% Boer x 25% Carpatina) had the highest value of the thigh section, this being 108.78 cm^2 higher by 28.4% compared to the Carpatina breed kids, the differences being significant ($p<0.05$);
The area of the section of the Longissimus Dorsi muscle was higher in R_1 hybrids by 65.7% (highly significant differences, $p<0.001$) compared to the batch of kids from the Carpatina breed and by 17.1% higher than F_1 hybrids (significant differences, $p<0.05$);
The area of the femur section was between 2.84 cm^2 and 3.20 cm^2, the differences between the 3 groups being insignificant ($p>0.05$);
The thigh muscularity index had values between 0.37 and 0.48, the highest value being found in the R_1 hybrids, 29.7% higher than the batch of kids from the Carpatina breed (very significant differences, $p<0.001$) and higher than the hybrids F_1 with 9.1%, the differences being significant ($p<0.05$);
The obtained data reveal the superiority of the R_1 goat population (75% Boer x 25% Carpatina), clearly resulting in the advantages of crossing the Carpatina breed with the Boer breed in terms of increasing the quantitative and qualitative production of meat in the goat species. At R.D.I.S.G.B. Palas Constanta, a native breed of goats specialized in meat production (Boer 75%, Carpatina 25%) is being prepared, which will contribute, after approval, to increasing the quantity and quality of meat production among goat farms.

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